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FACTORS AFFECTING THE MEASUREMENT OF STRAIN

By

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One of the most common physical tests on vulcanised rubber is the measurement of the strain against stress characteristics of a test piece of uniform cross section. The measurement is usually carried out on a tension testing machine, the test piece being stretched between two clamps or pulleys which are separated at a constant rate. The stress and corresponding strain can be recorded autographically and from the recording can be determined the stress required to produce a given elongation (modulus), the elongation at a given stress (strain), the elongation at break and the final breaking tension stress. For a natural rubber gum vulcanisate containing no fillers the modulus is generally measured at 600% elongation since the stress at lower elongation is small and the percentage error arising in its estimate correspondingly large. It has been shown by FIELD[1] that at elongations in excess of 200%, vulcanised rubber contains an appreciable proportion of crystallised material, the amount of crystallisation is dependent on temperature, the state of vulcanisation, and other factors. This effect, in combination with other uncontrolled variations, results in considerable disparities between the results of high elongation modulus tests in different laboratories using similar test pieces. It is therefore desirable that any accurate measurement of the stress strain properties for the evaluation of natural or synthetic rubber should be made at elongations less than 200%.

An apparatus was developed by U.S. Natural Bureau of Standards[2] which has the advantages of estimating the strain at elongations unaffected by crystallisation both rapidly and accurately. The apparatus is designed so that the load on the test specimen can be adjusted to apply a constant stress on the unstrained section of the test piece over a practical range of cross sectional areas. The application of the correct load is semi-automatic, but although the mechanism is relatively simple its maintenance may be a problem in the producing countries in the East, especially on isolated stations. A modified but similar apparatus was designed by the British Rubber Producers' Research Association (BRPRA) and has been described by FLETCHER[3]; it has some advantages over the more elaborate model recommended by the Bureau of Standards, being inexpensive and easily maintained. There are however several minor disadvantages associated with the simpler strain tester which are mentioned below; nevertheless the apparatus has proved to be an invaluable tool in the evaluation of the physical characteristics of natural rubbers.

The extensive employment of the strain test in the classification of natural rubber has resulted in a much more critical assessment of the strain test than is usually given to new apparatus. This paper describes some of the work carried out in the R.R.I.M. in connection with this measurement.

GENERAL PROCEDURE EMPLOYED FOR PREPARATION OF COMPOUND, TESTING OF SPECIMENS AND ANALYSIS OF RESULTS

All the experiments reported below were carried out using the A.C.S. No. 1 formulation, *i.e.* smoked sheets 100gm, zinc oxide 6gm, sulphur 3.5gm, stearic acid 0.5gm, and mercaptobenzthiazole 0.5gm. The compounding ingredients were added in the form of masterbatches prepared with a small quantity of rubber, with medium modulus characteristics in the vulcanised state. This rubber weighing 5gm, forms a part of the 100gm in the original formula. The mixing was carried out on a 6 inch diameter roll laboratory mill with a time controlled mixing procedure, so that the Mooney viscosity of the compound for each mix was 40 ± 3.

All test pieces were vulcanised in a steam heated hydraulic press for 40 minutes at 140°C on removal from the moulds, except in section *f* (page 157); they were cooled rapidly by immersion in water at laboratory temperature.

The testing temperature varied between 28 and 30°C, hence none of the results may be immediately applicable to laboratories operating in temperate climates. However, limited results carried out by the I.F.C., who were advised of the rapid test method in 1952, indicate that the correlation described in section *b* (page 152) may be independent of small temperature differences. Generally it should be noted that the temperature coefficient of strain measurements on test pieces, prepared as described here, is of the order of -0.2/°C. The strain measurement is made one minute after the application of a stress of 5 kgm/sq cm and is the increase in the elongation of a 10 cm central length of a uniform section dumbbell.

The error in the measurement of strain is proportional to the mean value of the strain and strictly a logarithmic transformation should be employed prior to statistical analysis. Such transformations, however, do not appear to affect the significance of large effects and throughout this paper the simple although unorthodox procedure is employed.

PREPARATION OF TEST PIECES

It has been found that the physical properties of a vulcanisate are affected by the period both between mixing and vulcanising and that between vulcanising and testing. The variation for most physical properties is rapid in the first few hours after mixing and vulcanising but becomes small after about 24 hours. This effect has led most National Standards Institutions to advocate a period of storage of

about 24 hours between both mixing and vulcanising, and vulcanising and testing. Thus the time required to evaluate a sample of rubber is in excess of two days; in practice the time interval is generally nearer three days due to the need to mix enough compounds to use the complete capacity of the vulcanising press. This delay has considerable disadvantages in the operation of a testing laboratory, whether it is employed in the producing countries or for check tests on industrial production. Although it was realised that any rapid test would not produce results similar to those obtained using a standard procedure, it was hoped that the results of the rapid and normal tests could be correlated and the correlation used for the determination of the latter from the former measurement.

a VARIATION IN MIXING, VULCANISING, TESTING CYCLE

Two samples of smoked sheet of different technical properties in the vulcanised state were compounded in the A.C.S. No. 1 formulation and subsequently vulcanised in the form of strain dumbbells. The time cycle of the mixing, curing and testing procedures was varied as shown in TABLE I.

TABLE I: VARIATION IN STRAIN DUE TO DIFFERENT MIXING, CURING AND TESTING CYCLES

Time between mixing & curing in hours $[T_2]$	*Modulus of rubber*	*Time between curing & testing in hours* $[T_1]$			
		0	2	4	24
0	*medium*	82.6	81.3	79.6	81.5
	low	104.9	102.3	98.3	99.2
2	*medium*	82.7	80.7	81.5	80.6
	low	102.9	100.1	98.7	97.4
24	*medium*	81.3	79.2	78.3	78.4
	low	97.3	94.3	90.8	89.8

A statistical analysis of this data indicates that both the effects due to T_1 and T_2 are significant at the 5% level. Consideration of the means of test specimens produced under similar conditions shows that the two effects are of similar magnitude.

TABLE II: EFFECT OF CONDITIONING PERIOD ON PROPERTIES OF VULCANISATE

T_1 *in hours*	0	2	4	24
Mean strain	92.0	90.0	87.9	87.8
T_2 *in hours*	0	2		24
Mean strain	91.2	90.5		86

This experiment suggests a rapid method for the measurement of strain. Provided that the time between the three major operations in the preparation and testing of the vulcanised specimens can be restricted to less than two hours, the results although different from those attained by the normal methods may be reproducible. The suggested procedure with a press vulcanising 32 test specimens at one loading is to mix this number of compounds (taking about 1½ hours) and test the vulcanisates immediately after immersion in cold water for about 10 minutes. The whole procedure takes less than 3 hours for this number of test specimens.

b CORRELATION BETWEEN RAPID AND NORMAL TEST

A large number of rubbers was examined using the procedure outlined above with the exception that the number of test pieces vulcanised together varied between 3 and 12. corresponding to the intake of samples from a packing house. Subsequently tests were made by the normal procedure using the same compounded stock. In *Figure 1* some of the strain results of the rapid test are recorded against the corresponding value obtained by the normal test method. The correlation coefficient of these results, uncorrected for variation in the cross sectional area of the test pieces, is

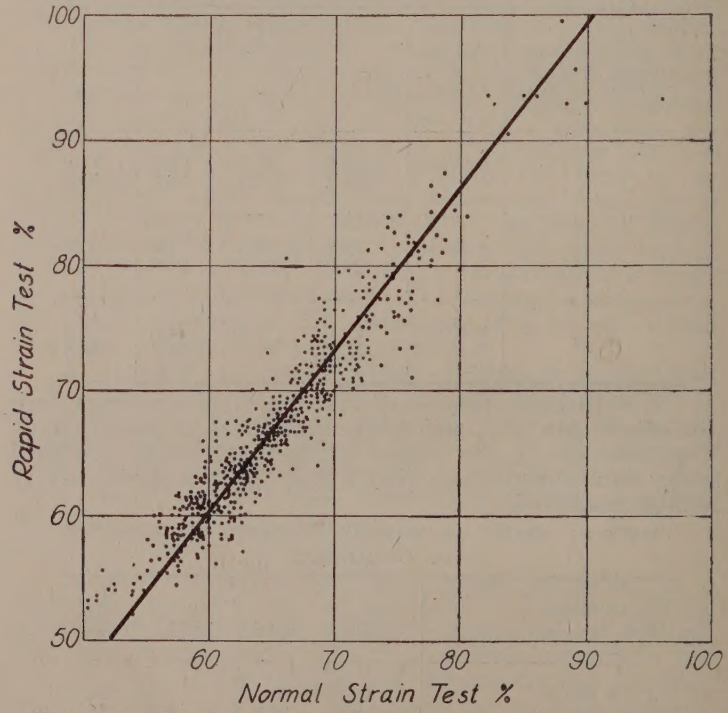

Figure 1. Correlation between strain results obtained by rapid and normal tests

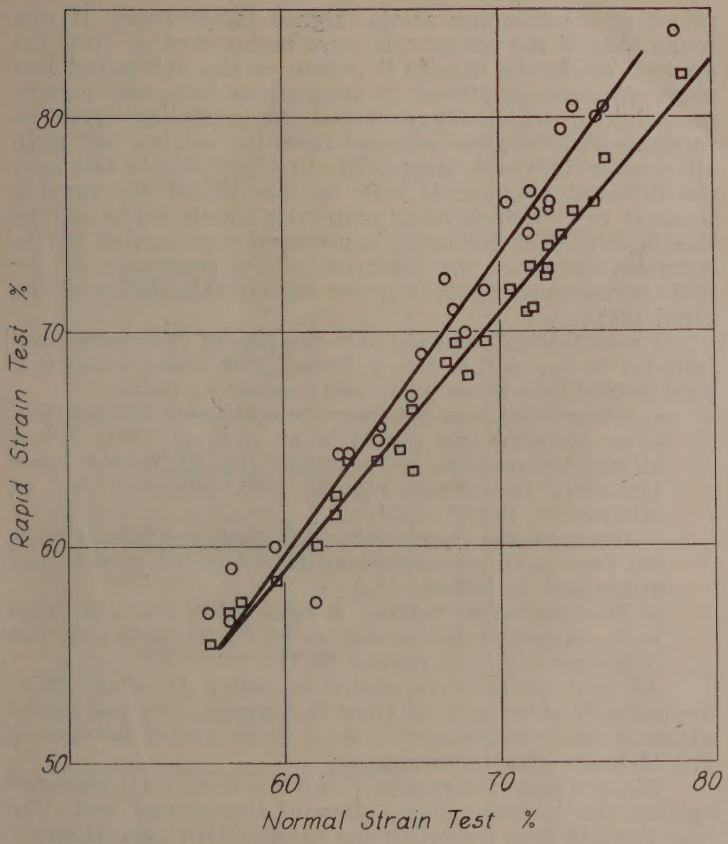

Figure 2. Comparison of the rapid test with and without controlled conditioning of compound

□ *Free cooling of compound for rapid test*

○ *Compound conditioning at 70°C for rapid test*

0.952 with 506 degrees of freedom. The equation of the best straight line drawn in *Figure 1*, for estimating the most probable value of the normal test result from measurements by the rapid test, is as follows.

$$S_N = 13.15 + 0.7746 S_R$$

c CONDITIONING OF COMPOUND AT MILL TEMPERATURE

It will be realised that the rapid method of test introduces considerable variations in the factors T_1 and T_2 if 32 test specimens are examined at the same time. For example the first test compound will be conditioned at temperatures varying from about 70°C (the mixing temperature) to 28°C (room temperature) for about 1½ hours, whereas the last compound will have had a very short

period of conditioning at the higher temperature. It was found that if the compounds were maintained at 70°C for up to 2 hours the change in strain of the vulcanised test piece was not significant in comparison with the experimental error, which suggests that the compound should be retained at 70°C after removal from the mixing mill until all mixing had been completed. In this manner although the different compounds may be conditioned for varying times at 70°C their physical properties should not be altered significantly. The following experiment was carried out to determine whether the retention of the compound at the mill temperature would improve the reproducibility of the rapid test.

Pieces from 29 blended bale samples of RSS were compounded in the A.C.S. No. 1 formulation. Each compound was divided into three parts and treated as follows:

i A 5gm blank was cut from the compound immediately after sheeting and placed in an oven at 70°C. When all the compounds were mixed the 22 blanks were placed in two strain moulds and vulcanised for 40 minutes at 140°C. (S_1)

ii When all the compounds were prepared blanks were cut from each compound and placed in the moulds and vulcanised as before. (S_2)

iii One day after mixing, a 5gm blank was cut from each compound vulcanised as in *i* and tested on the following day. (S_3, normal test)

All test pieces were cooled in water at about 28°C immediately after removal from the moulds. The test pieces obtained from treatments *i* and *ii* were tested between $\frac{1}{2}$ and $1\frac{3}{4}$ hours after vulcanisation.

Figure 2 gives the results of the two rapid tests recorded against the corresponding values of the normal test. The best straight lines for predicting values of the normal strain test from those of the rapid test are drawn for both relations. The correlation coefficients of the rapid tests with the normal test S_1/S_3 and S_2/S_3 are 0.98 and 0.99 respectively, there is considerably less probability than 1 in 1000 of such values occurring by pure chance. The two lines are significantly different with respect to both slope and axis interceptions. An examination of the residual variance about the regression line indicates that there is less variability associated with the free cooling rapid test than with that conditioning the compound at the mill temperature. Comparison of these data with those given in *Figure 1* suggests that all the data can be regarded as being of the same population.

d MIXING, CURING AND TESTING ERRORS WITH THE NORMAL AND RAPID TEST METHODS

Since with the rapid method the rubber would be exposed for short periods to uncontrolled variations, it was expected that the total error associated with the mixing, curing and testing would be less than with the normal method. The effects of all three operations on the

TABLE III: RESULTS OF RAPID AND NORMAL TESTS CORRECTED FOR CROSS SECTIONAL AREA ERRORS

Sample	STRAIN [40 minutes at 140°C]					
	Day 1		Day 2		Day 3	
	Rapid	Normal	Rapid	Normal	Rapid	Normal
1	62.5, 62,5	60.0, 59.5	62.0, 62.5	60.5, 60.0	63.0, 62.0	59.5, 60.0
2	60.0, 59.0	59.5, 58.5	59.5, 58.5	54.5, 55.0	59.5, 58.5	57.0, 57.5
3	84.0, 83.5	77.5, 77.0	80.5, 82.5	77.5, 78.5	83.0, 80.0	79.5, 78.0
4	75.0, 75.5	74.5, 75.0	75.0, 74.0	72.5, 72.0	73.0, 74.5	71.5, 72.0
5	93.5, 93.0	90.0, 89.5	92.0, 92.0	84.5, 86.0	93.0, 93.0	86.0, 85.5
6	85.0, 83.0	82.5, 80.0	84.0, 84.5	79.0, 80.5	82.5, 82.0	78.5, 77.5
7	111.5, 110.0	99,5, 100.0	112.0, 114.0	101.5, 100.5	114.0, 110.5	98.0, 98.5
8	111.0, 113.5	102.0, 103.5	113.0, 113.0	97.5, 98.5	109.5, 112.0	99.0, 97.5
Total difference between dupl. test pieces	8.5	7.5	7.0	7.5	13	6.5

TABLE IV: COMPARISON OF ANALYSIS FOR RAPID AND NORMAL TESTS

Source of variation	*d.f.*	*Rapid test* S.S.	M.S.S.	*Probability*	*Normal test* S.S.	M.S.S.	*Probability*
Between samples	7	16891.4531	2413.0647	<0.001	10824.4167	1546.3452	<0.001
Between days	2	5.1982	2.5991	<0.02	40.3229	20.1614	0.05
$S \times D$	14	21.2188	1.5156	>0.02	76.6771	5.4769	<0.001
Between duplicate test pieces	24	28.3750	1.1823		13.5000	0.5625	
Total	47	16946.2451			10954.9167		

two methods of test are compared in the experiment described hereunder.

Eight blended samples were selected, six were RSS and two thin pale crepe, giving a fairly wide range of physical properties in the vulcanised state. One mix was made from each rubber on each of three days; four strain test pieces were vulcanised from each mix, two by the rapid method and two by the normal procedure. The mixings were carried out in a random order within days.

The results of the measurements corrected for cross sectional area variations are given in TABLE III. An analysis of these results (not reported) shows that there is a significant interaction between samples and method of test. This tendency to change the order of strain values by altering the method of test will cause little trouble in practice, since confusion is only liable to occur between rubbers of very similar strain properties. The two sets of results obtained by the rapid and normal tests are analysed separately in TABLE IV.

It will be noticed that the rapid test is associated with a slightly greater between duplicates error, which confirms the difference between duplicate test pieces given in TABLE III. It will be seen that on days 1 and 2 the rapid test has similar reproducibility between duplicate test pieces, to that of the normal test, but that on day 3 there is a greater error associated with the rapid test. However the mixing, curing, testing error, which can be estimated from the between days' variance, is considerably less for the rapid test as is also the interaction between days and samples.

e APPLICATION OF RAPID METHOD TO OTHER PHYSICAL TESTS

Sixteen rubbers were compounded in the A.C.S. No. 1 mix and vulcanised in the form of Schopper discs. Subsequently the strain, modulus at 660% elongation in kgm/sq cm, elongation at break in % of original internal circumference of the ring, tension strength of ring in kgm/sq cm, and B.S. hardness in B.S.°, were measured. The mixing, vulcanising and testing cycles were carried out by the rapid and normal methods. The correlation between the results of the two tests are given in TABLE V with the equations of the best straight line.

TABLE V: CORRELATION BETWEEN RAPID AND NORMAL PROCEDURES FOR DIFFERENT PHYSICAL TESTS

Test	*Correlation cœfficient*	*d.f.*	*Probability*	*Equation of regression line*
Modulus	0.978	14	$<.001$	$M_N = 4.85 + 0.9783\ M_R$
Elongation at break	0.977	14	$<.001$	$E_N = 125.3 + 0.8512\ E_R$
Tension strength	0.926	14	$<.001$	$T_N = 16.77 + 0.9396\ T_R$
Hardness	0.998	14	$<.001$	$H_N = 1.43 + 0.9756\ HR$

These results indicate that the rapid test procedure can be used for a number of physical tests and is capable of predicting the values which would be obtained by normal standard procedures. As expected the relation between the two methods when measuring tension strength is associated with the most scatter about the regression line although the correlation coefficient is still highly significant.

f COLD WATER IMMERSION OF TEST PIECE AFTER VULCANISATION

Most national standards recommend that the test pieces should be immersed in cold water for ten minutes after removal from the vulcanising moulds. 192 compounds were prepared and two strain specimens vulcanised from each; one test specimen was allowed to cool to room temperature without any special control, the other was immersed in water at room temperature after removal from the mould. The mean values for the chilled and unchilled specimens were 81.35 and 81.40 respectively, indicating that little difference in low elongation strain measurements is introduced by the rapid cooling of the test pieces.

THE VARIATION IN STRAIN MEASUREMENTS DUE TO ERRORS IN THE CROSS SECTIONAL AREA OF THE TEST SPECIMEN

Operating under laboratory conditions it would be possible with the strain moulds employed with the B.R.P.R.A. strain tester to avoid the larger fluctuations in the cross sectional area of the test pieces by the selection of test pieces. In practice however a testing station working with a large input of samples can in general only vulcanise one or two test specimens of each sample and the problem of correction for variation in cross sectional area becomes acute. The most satisfactory solution to this problem would be the design of an improved mould, and work is in progress with this end in view. Temporarily a system of correction has been introduced in Malaya based on the following theory.

For small variations in strain it has been shown experimentally that ds/da = constant = $-K_s$, where s is the measured strain value, corresponding to a test specimen section of a sq cm.

The values of K_s for different values of strain can be calculated indicating a relation of the form $K = bS + c$ where S is the true strain value corresponding to a section of 20 sq mm.

Then $ds/da = -K = -(bS + c)$

$s = -bSa - ca + R$ where R is a constant with respect to a

But $S = s + \delta s = -bS\ (a + \delta a) - c\ (a + \delta a) + R$

$\therefore\ S - s = -bS\ \delta a - c\ \delta a$

$S = (s - c\ \delta a)\ /(1 + b\ \delta a)$ . . . . [1]

When ds/da is small, S approaches $-c/b$

and then $s = -c/b$ . . . . . [2]

BLACKWELL[4] has proposed a similar equation to [1] based on the assumption that stress strain curves can be represented to a first approximation by a relationship of the form

$$S = aF^2 + bF$$

where S and F are the strain and stress respectively and a and b are constants independent of the physical characteristics of the rubber.

Nine samples of smoked sheet of different physical characteristics in the vulcanised state were compounded in the A.C.S. No. 1 formulation and sixteen test pieces vulcanised from each compound in the same mould. The strain value of each test piece was measured and the corresponding value of the cross sectional area of the central test length. The cross sectional area was determined by cutting approximately 7 cm from the central portion of the dumbbell using a parallel bladed cutter and a Schopper ring cutting press. The standard deviation in the cut length for 12 test specimens as measured by a comparator was $\pm$ 0.14 mm and the concavity of the end sections was almost imperceptible when the knife edges were sharp and the cut made rapidly. From the mass of the central length and the specific gravity of the rubber the area of the section of the test pieces was calculated.

In order to determine which dimension was primarily associated with the variation in cross sectional area, measurements were made with a dial gauge micrometer fitted with a flat foot. This method usually gives too small an assessment of the section presumably due to the compression of the test piece under load; the average reduction in section is of the order of 1%. Nevertheless the measurements indicate that the variation in area is mainly associated with the width of the test piece rather than the thickness, suggesting that the mould cavities are being distorted laterally during service.

The correlation coefficient, with fourteen degrees of freedom, between the strain and the cross sectional area measurements for the nine compounds are given in TABLE VI with the corresponding values of S and K.

The equation of the best straight line for deriving values of K from S is

$$K = 4.836 - 0.154\ S$$

thus giving the appropriate values of the constants a and b in equation [1].

Using equation [1] and the values of the constants determined, a series of lines were constructed relating the measured and true strain for different errors in the cross sectional area of the dumbbell. The correction curves are given in *Figure 3*; it will be noticed that the error is small for vulcanisates with low strain or high moduli, the correction approaching zero when the strain is of the order of 31 units. At higher strain values the correction is large; at $S = 110$ it is of the order of $\pm$ 7 units for $\pm$ 0.6 sq mm error in the area of the section.

TABLE VI: CORRELATION BETWEEN STRAIN AND SECTION OF TEST PIECE

Compound	1	2	3	4	5	6	7	8	9
Correlation cœfficient	– 0.80	– 0.84	– 0.82	– 0.86	– 0.78	– 0.76	– 0.89	– 0.90	– 0.74
Strain [*S*]	66.7	89.5	67.3	82.2	60.0	99.8	100.5	61.0	87.3
K	– 6.50	– 11.57	– 4.38	– 6.60	– 3.98	– 12.30	– 9.08	– 5.62	– 6.81

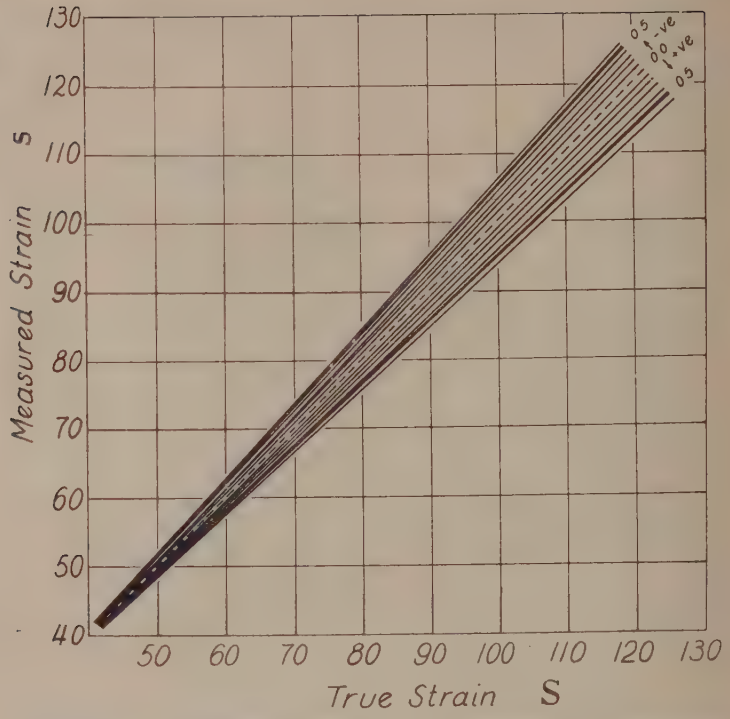

Figure 3. Correction curves for cross sectional area variations from + 0.6 to − 0.6 sq mm

A more convenient method of correcting for cross sectional area variations in strain measurements is to obtain a similar series of curves for the mass of a fixed length of test piece; a mean value of the specific gravity of the A.C.S. No. 1 compound should then be used. The variations for different smoked sheets are comparatively small and the errors introduced by this assumption small, of the order of 0.4%. The procedure then becomes: measure the strain, cut the central test length from the specimen and weigh it, find the true strain for a test piece of this section and measured strain from the curves.

APPLICATION OF THE CORRECTION—Five test specimens were prepared from each of three rubbers of different intrinsic physical properties. The strain and cross sectional area of each test specimen was measured and the corrected strain value determined. The results are given below in TABLE VII.

A statistical analysis of these data shows that the correction reduces the standard deviation of the measurement from ± 3.9 to ± 1.8 units of strain.

TABLE VII: CORRECTION OF STRAIN FOR CROSS SECTIONAL AREA OF TEST PIECE

Rubber	*C.S.A. sq mm*	*Measured strain*	*Corrected strain*
High strain	19.93	105.0	104.0
	19.50	108.0	103.0
	19.86	106.5	105.0
	20.09	98.5	99.5
	20.52	93.5	98.5
Medium strain	19.88	82.0	81.0
	20.36	81.0	84.0
	19.72	86.0	83.5
	20.19	81.0	82.5
	20.46	78.5	82.0
Low strain	20.44	58.5	60.5
	20.42	58.5	60.5
	20.16	59.5	60.5
	19.55	61.0	59.5
	20.18	60.0	61.0

CONCLUSIONS

1. Although alteration of the mixing, vulcanising and testing cycle for the measurement of strain does affect the physical properties of the final vulcanisate, a high degree of correlation can be obtained between the results of the rapid test and the normal test. The rapid test, which will not consume any more man hours than the normal test, can be fitted in to the normal daily procedure with little loss of testing capacity, and provides satisfactory data in a period of three hours for thirty two test specimens whereas more than two days are needed by the normal standard procedure.
2. The mixing, curing, testing error associated with the measurement by the rapid method is less than that obtained with the normal test method.
3. The rapid method can be used for predicting the results which would be obtained by many physical tests carried out by standard procedures and would therefore be generally useful for control measurements in industrial concerns.

4. Isothermal conditioning of the compounded stock after mixing does not appear to reduce the error associated with the rapid test but does alter the relation between the rapid and normal tests.
5. Immersion of test specimens in cold water after vulcanisation does not improve reproducibility or alter the value of the strain measurement.
6. Moulded strain specimens are liable to vary in respect of cross sectional area. Such variations can produce considerable errors in strain measurements, particularly with rubbers of high strain or low modulus characteristics. A simple method for the correction of these errors is advanced which increases the reproducibility of the strain test.

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FRACTIONS FROM HEVEA BRASILIENSIS LATEX CENTRIFUGED AT 59,000g

By
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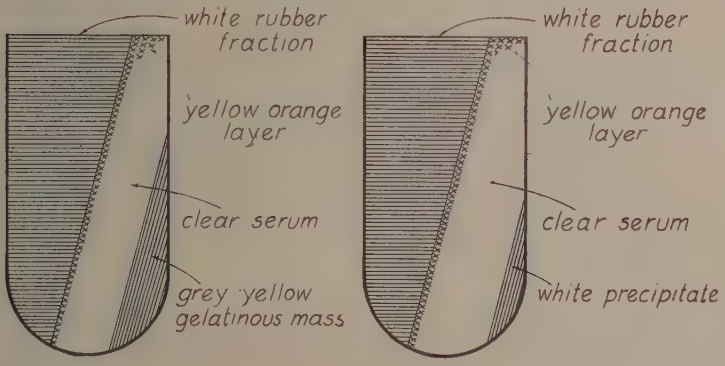
HOMANS and VAN GILS[1] have separated fresh latex, by centrifuging at 2,000 r.p.m. (*ca* 1,000 g) into two fractions, white and yellow, both consisting mainly of rubber particles and serum. They also reported the discovery of another discrete phase in fresh latex, which they called 'lutoids' and which were found mainly in the yellow fraction. HURET[2] has described the separation of ammoniated latex at 400,000 g into a white fraction, a yellow layer and clear serum. We have obtained four distinct fractions on centrifuging fresh latex at 20,000 r.p.m. (59,000 g) and these have not previously been described, although MCCOLM[3] has reported on the sludge obtained at 40,000 r.p.m.

Latex was collected from a field of mixed clonal seedlings at the Rubber Research Institute of Malaya Experiment Station and cooled in an ice/water mixture within an hour of tapping the first tree. Part of the latex was weighed into Lustroid (celluloid) tubes fitted with air tight caps and spun at 59,000 g in a refrigerated vacuum centrifuge* at 5°C for three quarters of an hour. Another portion of the latex was ammoniated to 0.5% NH_3 by weight, using a 20% solution. Part of this latex was centrifuged with the fresh latex and part after 24 hours. *Figure 1* is diagrammatic of the separations obtained.



a *Fresh latex* b *Latex containing 0.5% NH_3*

Figure 1

The fractions were separated by puncturing the tube at the top and the bottom of the serum fraction and allowing the serum to run out. The top portion of the serum was

* Spinco Ultracentrifuge Model L

TABLE I: ANALYSES OF FRACTIONS

Determination	*Latex fraction*	*Fresh latex, stored in iced water and centrifuged 1 hour after collection*	*Latex containing 0.5% NH_3 centrifuged 1 hour after collection*	*Latex containing 0.5% NH_3 centrifuged 24 hours after collection*	*Fresh latex, not centrifuged*
Dry rubber content [% wt]	*Whole latex*	—	—	—	44.24
Total solids [% wt]	*Whole latex*	—	—	—	47.65
Nitrogen [% wt]	*Dried rubber*	0.21	0.21	0.25	0.57
	Dried serum	2.29	4.23	5.78	
	Dried bottom fraction	5.23	4.54	3.94	
Magnesium [% wt]	*Dried rubber*	0.01	0.01	0.01	0.07
	Dried serum	0.28	0.01	0.01	
	Dried bottom fraction	1.25	7.82	8.00	
Phosphorus [% wt]	*Dried rubber*	0.04	0.04	0.04	0.13
	Dried serum	0.67	0.54	0.63	
	Dried bottom fraction	2.06	8.00	9.62	
Potassium [% wt]	*Dried rubber*	0.04	0.08	0.05	0.42
	Dried serum	4.72	5.75	5.04	
	Dried bottom fraction	3.13	1.34	1.24	
Copper [% wt]	*Dried rubber*	0.00017	0.00021	0.00036	0.00040
	Dried serum	0.00594	0.00341	—	
	Dried bottom fraction	0.00439	0.00500	—	
Ash [% wt]	*Dried rubber*	0.28	0.35	0.26	1.16
	Dried serum	11.20	9.23	—	
	Dried bottom fraction	17.11	29.47	39.96	
Rubber hydrocarbon [% wt]	*Dried rubber*	96.3	—	96.6	90.6
	Dried bottom fraction	14.9	—	—	
Alcohol extract [% wt]	*Dried rubber*	1.88	—	2.24	6.54
	Dried bottom fraction	42.15	—	—	
Total acid value [mgm KOH/100 gm t.s.]	*Dried rubber*	34	—	62	301
	Dried bottom fraction	3,983	—	—	

TABLE II: APPROXIMATE DISTRIBUTION OF COMPONENTS AMONG THE FRACTIONS
(% wt of whole latex)

Determination	*Fresh latex centrifuged after 1 hour*			*0.5% NH_3 latex centrifuged after 1 hour*			*0.5% NH_3 latex centrifuged after 24 hour*		
	Rubber	*Serum*	*Bottom fraction*	*Rubber*	*Serum*	*Bottom fraction*	*Rubber*	*Serum*	*Bottom fraction*
Nitrogen	34	35	31	28	64	8	37	58	5
Magnesium	16	30	54	11	0.5	88.5	12	0.5	87.5
Phosphorus	34	54	12	19	29	52	24	26	50
Potassium	7	74	19	10	87	3	12	85	3
Copper	20	62	18	31	58	11	—	—	—
Ash	14	54	32	20	58	22	—	—	—

mixed with part of the yellow orange layer and some rubber particles. Both the top and bottom fractions were very viscous and did not flow. They were readily obtained by cutting open the Lustroid tube.

The fractions and a sample of the fresh latex were dried in air at 70°C and analysed. Results are given in TABLE I.

It was difficult to separate part of the serum from the yellow orange layer and hence the exact amounts of each fraction, except the bottom fraction, were not obtained accurately. Nevertheless, an approximate distribution of the various constituents among the fractions is given in TABLE II.

From the fresh latex, the top white fraction was a very thick cream of rubber particles, comprising roughly 60% of the whole latex and containing 70-80% solids. Most of this fraction could be redispersed in water.

The yellow orange layer was obtained mixed with serum and rubber particles. Under the microscope considerable numbers of spherical yellow particles were seen, either singly or in small clusters. These were very similar to the description given by FREY-WYSSLING[4] of the yellow globules which he observed in ammoniated latex.

The serum was clear and slightly brown in colour, comprising about 25% of the whole latex and containing 7% solids. It was somewhat viscous, frothed readily and appeared to contain most of the proteins, phosphorus, potassium, copper, ash and part of the magnesium present in the whole latex.

The greyish yellow bottom fraction comprised 12-15% of the whole latex and contained 12% solids. It was very compact and on standing in air it slowly darkened to a dark brown finally becoming black. It did not coagulate but remained as a thick paste, which did not appear to dissolve in water. In ammonia solution it slowly dissolved to give a brown solution and a white precipitate, which was crystalline.

Microscopical investigations of the bottom fraction, before and after mixing with water, ammonia and sodium citrate solutions, showed it to consist of a tightly packed mass of gel-like 'islands' similar to the lutoid 'islands' found in fresh latex and described by HOMANS and VAN GILS[1]. These islands had a particulate structure and when ammonia solution was added many particles in Brownian movement could be observed. The particles could be rubber or lutoid globules such as are found in very fresh latex or in latex which has been collected into sodium citrate solution. After dissolving in ammonia for a few days, many particles which appeared to be rubber were seen and also a few yellow Frey-Wyssling particles. This fraction contained most of the magnesium and taking the nitrogen as being protein it consisted of about 40% alcohol extractables, about 30% protein, 17% ash and 15% rubber. The presence

of rubber could be attributed to rubber particles being trapped in the lutoid agglomerates.

Ammonia in the latex appeared to dissolve or disperse the lutoid fraction, giving in its place a white precipitate. The effects of the ammonia took place rapidly as will be seen by comparing the analyses of fractions from the ammoniated latex (a) centrifuged almost immediately and (b) after 24 hours. The bottom fraction from (a) was slightly larger than that from (b) indicating incomplete dispersion. The top white fraction and the orange yellow layer from the ammoniated latex, were similar to those from the fresh latex.

More serum was obtained from the ammoniated latex; about 40% of the whole latex containing 9% solids. It was cloudy and compared with the serum from the fresh latex it contained more nitrogen and potassium, about the same proportion of copper, less phosphorus and practically no magnesium.

The white precipitate at the bottom of the tube was only about 2% of the whole latex, and contained 32% solids. Compared with the lutoid fraction from fresh latex it contained more magnesium and phosphorus and less nitrogen, potassium and copper. Under the microscope it was seen to consist almost entirely of star shaped crystals. This precipitate is likely to be the same as that which has previously been described in the sludge from ammoniated latex[3] and is probably a magnesium phosphate.

Conclusions from these observations are that four fractions can be separated from fresh latex by centrifuging at 59,000 g: a thick cream of rubber particles; a layer of orange yellow Frey-Wyssling globules below the rubber; clear serum; and a gelatinous greyish yellow lutoid fraction at the bottom of the tube. Ammonia in the latex appeared to dissolve or disperse the lutoid fraction, forming an insoluble magnesium phosphate.

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